

## FEATURES

- *CE Compliance to 89/336/EEC*
- *Recognized Component to UL 508C*
- Velocity mode operation from motor Hall sensors or quadrature encoder
- +5V @ 200mA powers Hall sensors and encoder
- Drives motors with 60° or 120° Halls
- Enable polarity selectable to +5 or ground active
- **Single supply voltage: 18-55VDC**
- **5A continuous, 10A peak more than double the power output of servo chip sets**
- **Fault protections:**  
**Short-circuits from output to output, output to ground**  
**Over/under voltage**  
**Over temperature**  
**Self-reset or latch-off**
- **2.5kHz bandwidth**
- **Wide load inductance range: 0.2-40 mH.**
- **+5,+15V Hall power**
- **Separate continuous, peak, and peak-time current limits**
- **Surface mount technology**

## APPLICATIONS

- Velocity loops for PLC's or for speed controls
- Belt, fan, or spindle drives

## THE *OEM* ADVANTAGE

- **Conservative design for high MTBF**
- **Low cost solution for small brushless motors to 1/3 HP**  
**Small size, SMT technology**



## DESCRIPTION

Model 505 operates three-phase DC brushless motors in tachless velocity loops using Hall signals, or A&B signals from incremental encoders.

A 200mA, +5V output drives both Halls and encoders, or "commutating" encoders that output both Hall and A/B signals.

Frequency to voltage conversion of encoder signals provides velocity feedback in applications that do not require smooth operation around zero speed, where the velocity feedback becomes discontinuous. Spindle drives and other speed controls benefit from this form of velocity control. For highest speeds, use Hall feedback. For widest speed range, use encoder feedback.

Commutation is six-step ( trapezoidal ) using 60° or 120° Hall sensors on the motor.

Power delivery is four-quadrant for bi-directional acceleration and deceleration of motors.

The Model 505 features 500W peak power output in a compact package using surface mount technology.

An internal header socket holds components which configure the various gain and current limit settings to customize the 505 for different loads and applications.

Separate peak and continuous current limits allow high acceleration without sacrificing protection against continuous overloads. Peak current time limit is settable to match amplifier to motor thermal limits. Header components permit compensation over a wide range of load inductances to maximize bandwidth with different motors.

Logic inputs include remote inhibit/enable, and Pos/Neg enable inputs for connection to limit switches. Amplifier Enable input has selectable polarity for easy interface to all types of motion-control cards. Directional ( Pos & Neg ) enables always use fail-safe (ground to enable) logic.

Package design places all connectors along one edge for easy connection and adjustment while minimizing footprint inside enclosures.

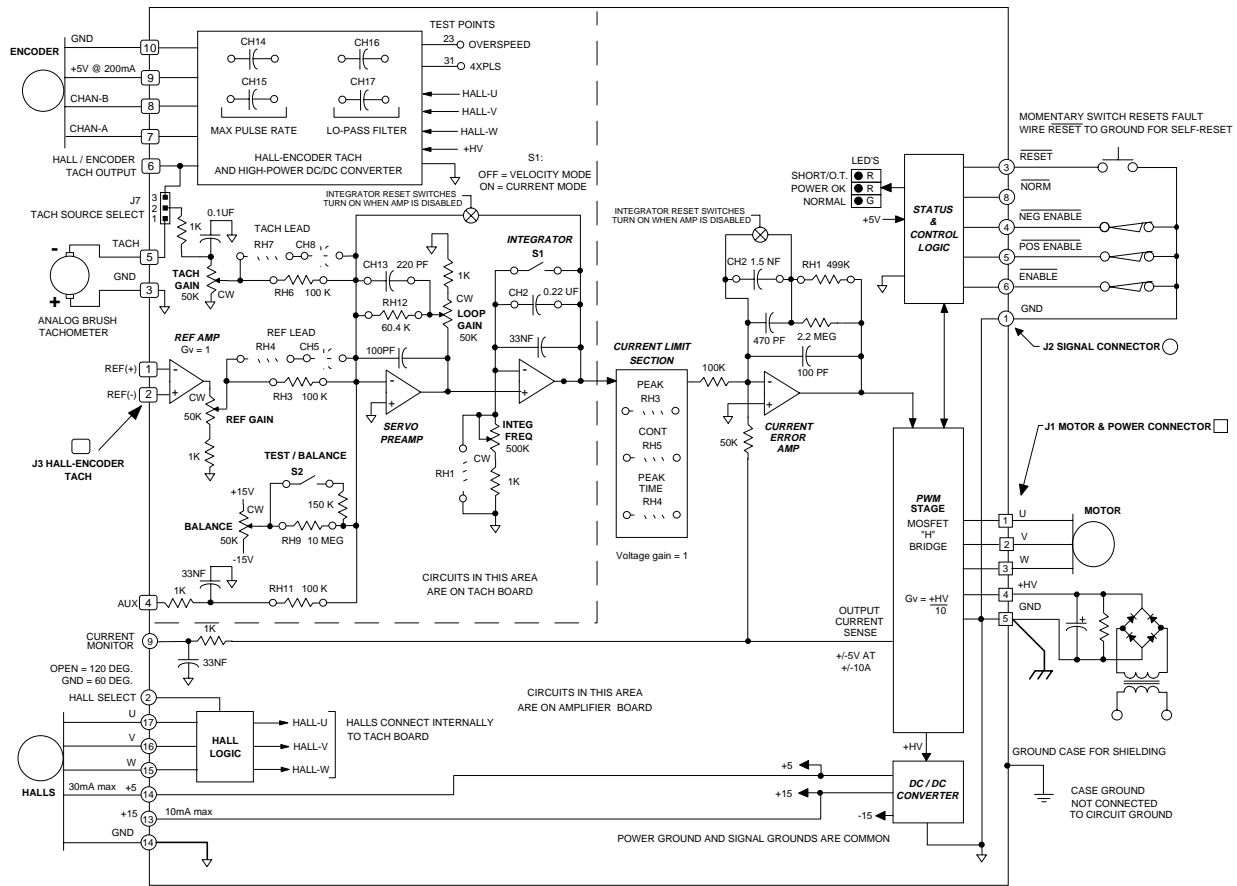
High quality components and conservative ratings insure long service life and high reliability in industrial installations.

A differential amplifier buffers the reference voltage input to reject common-mode noise resulting from potential differences between controller and amplifier grounds.

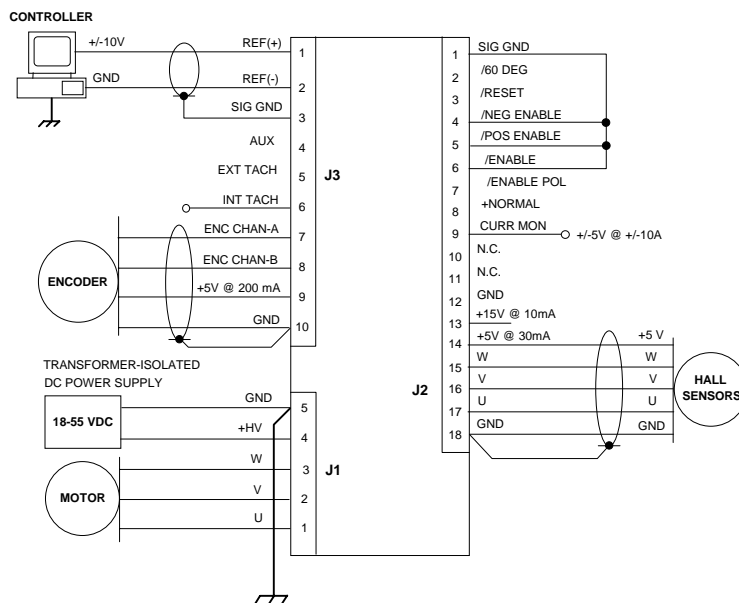
Output short circuits and heatplate overtemperature cause the amplifier to latch into shutdown. Grounding the /Reset input will enable an auto-reset from such conditions when this feature is desired.

# Model 505 DC Brushless Servo Amplifier

## FUNCTIONAL DIAGRAM



## TYPICAL CONNECTIONS



## TECHNICAL SPECIFICATIONS

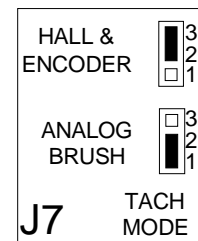
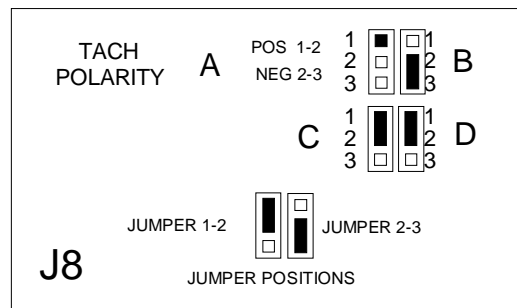
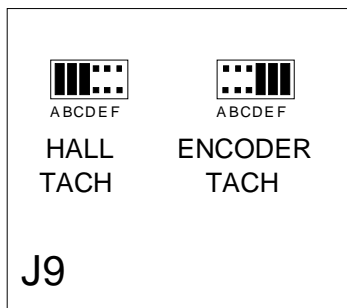
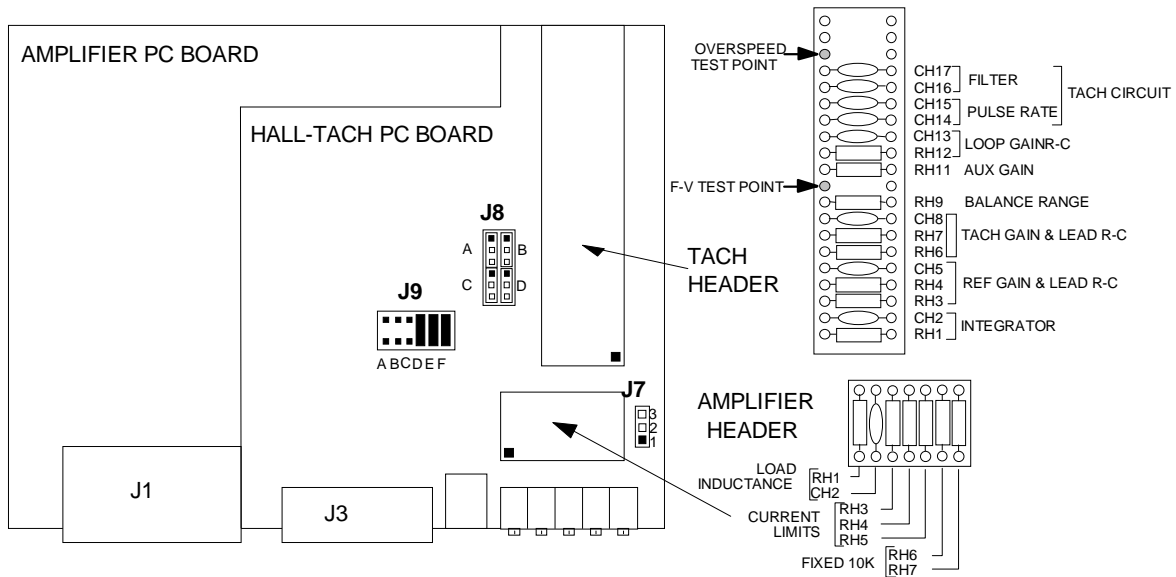
Typical specifications @ 25°C ambient, +HV = +55VDC. Load = 200μH. in series with 1 ohm unless otherwise specified.

### AMPLIFIER SPECIFICATIONS

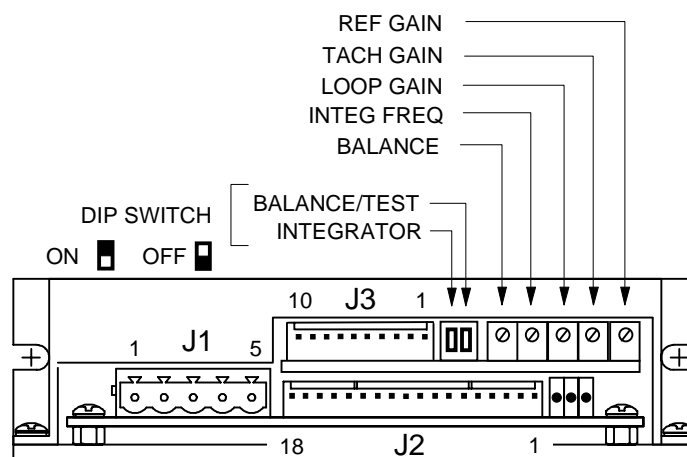
<b>OUTPUT POWER</b>	
Peak power	
Unidirectional	±10A @ 50V for 0.5 second, 500W
After direction change	±10A @ 50V for 1 second, 500W
Continuous power	±5A @ 50V, 250W
<b>OUTPUT VOLTAGE</b>	
	$V_{out} = \pm HV * (0.97) - (R_o)(I_{out})$ $R_o =$ amplifier output resistance, 0.4Ω
<b>MAXIMUM CONTINUOUS OUTPUT CURRENT</b>	
Convection cooled, no conductive cooling	±2A @ 35°C ambient
Mounted on narrow edge, on steel plate, fan-cooled 400 ft/min	±5A @ 55°C
<b>LOAD INDUCTANCE</b>	
Selectable with components on header socket	200 μH to 40mH (Nominal, for higher inductances consult factory)
<b>BANDWIDTH</b>	
Small signal	-3dB @ 2.5kHz with 200μH load
Note: actual bandwidth will depend on supply voltage, load inductance, and header component selection	
<b>PWM SWITCHING FREQUENCY</b>	
	25kHz
<b>ANALOG INPUTS</b>	
Reference +/- Inputs	Differential, 94kΩ between inputs, ±20V max
Auxiliary Input	Single-ended, 1kΩ/33nF input filter to RH11 on header
Tachometer	Single-ended, 1kΩ/0.1μF input filter to 50kΩ pot with tap to RH6, RH7 on header
<b>LOGIC INPUTS</b>	
Logic threshold voltage	HI: ≥ 2.5V , LO: ≤1.0V
Input voltage range	Gnd to <b>+5V maximum</b>
/Enable	LO enables amplifier (/Enable Pol open) , HI inhibits; 50 ms turn-on delay
/POS enable, /NEG enable	LO enables positive output currents, HI inhibits
/Reset	LO resets latching fault condition, ground for self-reset every 50 ms.
/Enable Pol (Enable Polarity)	LO reverses logic of /Enable input (HI enables unit, LO inhibits)
<b>LOGIC OUTPUTS</b>	
+Normal	HI when unit operating normally, LO if overtemp, output short, disabled, or power supply (+HV) out of tolerance
Definitions:	HI output voltage = 2.4V min at -3.2 mA max., LO output voltage = 0.5V max at 24 mA max. <b>+5V maximum, do NOT connect to devices operating at greater than +5V</b>
<b>INDICATORS (LED's)</b>	
Normal (green)	ON = Amplifier enabled, no shorts or overtemp, power within limits
Power fault (red)	ON = Power fault: +HV <18V OR +HV > 55V
Short/Overtemp (red)	ON = Output short-circuit or over-temperature condition
<b>MONITOR OUTPUT</b>	
Current monitor	±5V @ ±10A (2A/volt), 10kΩ, 3.3nF R-C filter
<b>DC POWER OUTPUTS</b>	
Hall +5VDC ( J2-14 )	30mA (Includes power for Hall sensors)
Hall +15VDC ( J2-13 )	10mA
Encoder +5VDC ( J3-9 )	200mA
<b>PROTECTION</b>	
Output short circuit (output to output, output to ground)	Latches unit OFF (self-reset if /RESET input grounded)
Overtemperature	Shutdown at >70°C on heatplate (Latches unit OFF)
Power supply voltage out of tolerance	Shutdown at +HV <18VDC or +HV >55VDC ( operation resumes when supply in tolerance )
<b>POWER REQUIREMENTS</b>	
DC power (+HV)	18-55 VDC @ 10A peak.
Minimum power consumption	2.5 W
Power dissipation at 5A output, 55VDC supply	10W
Power dissipation at 10A output, 55VDC supply	40W
<b>THERMAL REQUIREMENTS</b>	
Storage temperature range	-30 to +85°C
Operating temperature range	0 to 70°C baseplate temperature
<b>TACHOMETER SPECIFICATIONS</b>	
<b>MAXIMUM FREQUENCIES</b>	
F/V clock internal pulse rate	600,000 /sec
Encoder lines/sec	150,000 /sec
Hall cycles/sec	100,000 /sec
Note: F/V clock internal pulse-rate = encoder lines/sec X4, or Hall cycles/sec X6	
<b>LINEARITY</b>	
	< 0.1% of full scale over a 1000:1 rpm range
<b>SPEED RANGE</b>	
	1000:1 typical

# Model 505 DC Brushless Servo Amplifier

## INTERNAL SOCKETS & JUMPERS



## AMPLIFIER LAYOUT



J1 Motor & Power Supply  
J2 Amplifier Signals  
J3 Tach Card Signals

5 position Euro: Weidmuller BL-12594.6, Phoenix MSTB 2.5/5-ST-5.08  
18 position 0.1" centers: Molex 22-01-3187 with 08-50-0114 terminals  
10 position 0.1" centers: Molex 22-01-3107 with 08-50-0114 terminals

## CONNECTORS AND PINOUTS

### J1: MOTOR & POWER CONNECTIONS

Pin	Signal	Remarks
1	Motor phase U	Amplifier output to motor windings
2	Motor phase V	Amplifier output to motor windings
3	Motor phase W	Amplifier output to motor windings
4	+HV	18-55V DC power supply input
5	GND	Power supply return. Connect to system ground at this pin.

### J2: AMPLIFIER BOARD CONNECTIONS

Pin	Signal	Remarks
1	GND	Signal ground ( Note 3 )
2	/60° HALL	Ground for 60° Hall phasing, open for 120°
3	/RESET	Normally open. Ground to clear overtemp or short circuit fault. Wire to ground for self-reset from fault every 50 mS.
4	/NEG ENAB	Negative rotation enable (ground to enable, open inhibits)
5	/POS ENAB	Positive rotation enable (ground to enable, open inhibits)
6	/ENABLE	Amplifier enable. Ground to enable amp, open inhibits. 50 mS delay between Enable active and amp outputs ON
7	/ENABLE POL	/Enable polarity With J2-7 open, ground @ J2-6 enables amp. With J2-7 grounded: +5V or open enables amp, ground inhibits
8	+ NORMAL	HI (+5 V) if amplifier operating normally (No faults) LO if amp disabled, +HV over or undervoltage, overtemp, or output short circuit.
9	CURR MON	2A/Volt current monitor output (bipolar)
10		No connection. Pins used by tach card.( Note 2. )
11		No connection. Pins used by tach card. ( Note 2.)
12	GND	Signal ground ( Note 3 )
13	+15 V	+15 V at 10 mA Hall power ( total power from +5 and +15
14	+5 V	+5 V at 30 mA Hall power outputs not to exceed 200mW)
15	HALL W	W Hall input
16	HALL V	V Hall input
17	HALL U	U Hall input
18	GND	Hall ground ( Note 3 )

### J3: TACH BOARD CONNECTIONS

Pin	Signal	Remarks
1	Ref(+) Input	±10V reference input.
2	Ref(-) Input	Reference ground ( connect to gnd at reference voltage source )
3	Gnd	Brush tachometer (+), or reference cable shield
4	Aux Input	Auxiliary input ( single-ended analog input )
5	Ext. Tach Input	External brush tachometer (-), or analog velocity feedback
6	Int. Tach Output	Hall-encoder tach output ( ±10V at max pulse-rate )
7	Encoder A Chan	Quadrature encoder channel-A
8	Encoder B Chan	Quadrature encoder channel B
9	Encoder +5V	+5V @ 200mA powers encoder, or encoder and Halls
10	Encoder Gnd	0V or ground for encoder ( also connect to encoder cable shield )

#### Notes

- For motors with separate Halls and encoder, connect Hall +5V to J2-14 ( J2-13 if Halls require +15V ). Connect Hall ground to J2-18. Connect encoder to J3 ( +5V, gnd, and channels A, B )  
For motors with commutating encoders, or with Halls and encoders operating from same +5V supply, use +5V from J3-9 & ground to J3-10.
- Pins J2-10,11 are Ref inputs on model 503. DO NOT USE on model 505, these connect to tachometer board internally. Reference inputs are on tach card, J3 pins 1 and 2.
- All amplifier grounds are electrically common. J1-5, J2-1, J2-12, J2-18, J3-3, & J3-10 are all connected inside the amplifier. The amplifier circuitry is isolated from the case.

# Model 505

## DC Brushless Servo Amplifier

### APPLICATION INFORMATION

Follow these steps to place amplifier into service:

1. Setup amplifier header for motor inductance and current limits.
2. Establish correct phasing for motor & Hall connections.
3. Select tachometer header components for maximum motor speed.
4. Select tach card header components for low-pass filter.
5. Test & adjust potentiometers for optimal operation.

#### 1. MOTOR INDUCTANCE

*Note: for procedures 1 & 2, remove jumper from J7 on tach card, set switch S1 ON, and turn Loop Gain pot fully CCW. Ground J2-4,5,6 to J2-1 to enable amplifier.*

RH1 & CH2 on amplifier header socket match amplifier to motor inductance. For easy setup, use chart to select values closest to your motor inductance. To optimize compensation using function generator and oscilloscope: First replace CH2 with a jumper (short). Use reference input of square wave at  $\pm 1V$ , 10Hz. Select RH1 for the best transient response (lowest risetime with minimal overshoot). Once RH1 has been set, choose the smallest value of CH2 that does not cause additional overshoot or degradation of the step response.

Select values of RH3, RH4, and RH5 if motor current limits are less than amplifiers 5A continuous, 10A peak rating. Pick starting values from charts. Fine-tune limits by using current monitor and adjusting values for exact limit desired.

#### 2. MOTOR-HALL PHASING

1. Connect the motor Hall sensors to J2 based on the manufacturers suggested signal names. (A-B-C, R-S-T, and U-V-W are all used to name the Hall signals by different manufacturers). Use the required Hall supply voltage (+5 from J2-14 or +15V from J2-13). If Halls are connected to encoder, or if they come from a commutating encoder, use +5V from J3-9, ground to J3-10.
2. With the motor windings disconnected, apply power and slowly rotate the motor shaft. Observe the Normal (green) led. If the lamp blinks while turning then the 60/120° setting is incorrect. If J2-2 is open, then ground it and repeat the test. In order to insure proper operation, the correct Hall phasing of 60° or 120° must be made.
3. Turn off the amplifier and connect the motor leads to J1-1,2,3 in U-V-W order. Power up the unit. Apply a sinusoidal reference signal of about 1 Hz. and 1Vrms between J3-1 & 2 (Reference inputs).
4. Observe the operation of the motor as the current monitor signal passes through zero. When phasing is correct the speed will be smooth at zero crossing and at low speeds. If it is not, then power-down and re-connect the motor. There are six possible ways to connect the motor windings, and only one of these will result in proper motor operation. The six combinations are listed in the table below. Incorrect phasing will result in erratic operation, and the motor may not rotate. When the correct combination is found, record your settings.

	J1-1	J1-2	J1-3
#1	U	V	W
#2	V	W	U
#3	W	U	V
#4	U	W	V
#5	W	V	U
#6	V	U	W

### 3. TACHOMETER SETUP

*Note: for procedures 3-5, install jumper at J7 pins 2-3 on tach card, set switch S1 OFF. Begin with Loop Gain and Integ Freq pots fully CCW. If motor runs away, reverse position of jumper J8.*

#### GENERAL CONSIDERATIONS

Encoder tachometer mode gives the widest speed useable speed range combined the fastest velocity-loop response. Use Hall-tachometer mode for high-speed operation where no encoder feedback exists. Example: a 4-pole brushless motor with a 500 line encoder operating at 1500 rpm. The f/v clock pulse rate is 50,000 Hz for encoder feedback, and 300 Hz for Hall feedback. As speed drops, ripple will increase. At a standstill, there will be no feedback between Hall or encoder transitions, resulting in jitter. This may be acceptably small for an encoder application, or unacceptably rough for a Hall tach. Use the Enable input to disable the amplifier if zero-output is required.

#### MAXIMUM PULSE RATE

An f/v clock signal is generated that is 6X the Hall cycle frequency, or 4X the encoder line frequency. The maximum f/v clock rate is 600kHz. Before proceeding, check to make sure that your f/v clock will be in limits.

If the rate is greater than 600kHz, then maximum rpm must be reduced.

If the rate is acceptable, select the f/v capacitors CH14 & CH15 as follows:

#### HALL TACHOMETER

Install jumpers at J9-A,B,C. Choose CH14 & CH15 based on this equation:

$$C = \frac{1400}{\text{Poles} \times \text{rpm}} \quad (C = \mu\text{F})$$

#### ENCODER TACHOMETER

Install jumpers at J9-D,E,F. Choose CH14 & CH15 based on this equation:

$$C = \frac{1 \times 10^9}{\text{Lines} \times \text{rpm}} \quad (C = \text{pF})$$

Choose a capacitor with the closest value. This should produce a tach-voltage of about  $\pm 5V$  at the rpm used in the equations.

#### 4. LOW-PASS FILTER

The choice of low-pass filter will determine both the useable rpm range of the f-v converter and the effective response time of the velocity-loop ( or effective bandwidth ). For widest speed range, set the low-pass filter frequency to a lower value. For faster response times ( higher velocity loop bandwidth ) set the frequency to a higher value.

Hall tach applications may require much larger values of capacitor in the filter. Because Hall pulse rates will typically be as much as 100X less than encoder pulse rates, a low-pass filter frequency that gives satisfactory results at lower speeds may noticeably slow down the step response of the motor. Thus, Hall tach applications will be most useful for higher speeds such as spindle drives, blowers, and gear-drives.

As delivered, the 505 has a filter frequency of 159Hz. This should work well for encoder-tach modes with a wide variety of motors in the size range that the 505 can drive. This frequency is high enough so that the velocity loop response will be affected mainly by the rpm / volt gain, and tuning of the Loop Gain, and Integ Freq potentiometers. In general, use the lowest frequency possible that does not begin to slow down the response of the loop to a step input. This will give the widest rpm range.

#### 5. VELOCITY LOOP TUNING

Begin with S1 ON, Ref Gain pot fully CW, Tach Gain pot fully CCW, Loop Gain pot fully CCW. Previous steps must be performed to insure that motor is properly phased and rotates smoothly in both directions.

Rotate shaft slightly. If motor runs away, reverse position of jumper J8A. Motor should now be stable with no reference inputs.

##### Static Setup

Set switch S2 ON. Rotate Balance pot fully CW. This will be equivalent to applying +10V to Ref inputs. Measure tach voltage at J3-6. This should be about +5V if CH14 & 15 have been chosen correctly. Motor rpm can be measured by viewing any Hall signal and calculating as follows:

Where  $T_h$  is the *period* of one Hall signal ( can be U, V, or W ).

##### Dynamic Setup

Set switch S2 OFF. Use a function generator with a square wave output. Connect to reference inputs and adjust frequency so that motor can change direction and settle to a set speed. Connect oscilloscope to J3-6 to monitor tachometer voltage. If possible, also connect to J2-9, current monitor. Adjust Loop Gain pot for fastest response that does not produce oscillation or excessive ringing of either tach signal, or current monitor.

When Loop Gain is adjusted, set S1 OFF. Adjust Integ Freq CW until overshoot on tach signal rings and back off for stable response.

CW adjustment increases stiffness ( speed stability ), but too much will produce oscillation. With Loop Gain and Integ Freq adjusted properly, response to step inputs will be smooth, and free from oscillation.

#### GROUNDING & POWER SUPPLIES

Power ground and signal ground are connected internally in the Model 505. These grounds are isolated from the amplifier case which can then be grounded for best shielding while not affecting the power circuits. Currents flowing in the power supply connections will create noise that can appear on the amplifier grounds. This noise will be rejected by the differential amplifier at the reference input, but will appear at the digital inputs. These are filtered, but for lowest noise, leave the power-supply capacitor floating, and ground each amplifier at its power ground terminal. In multiple amplifier configurations, always use separate cables to each amplifier, twisting these together for lowest noise emission. Twisting motor leads will also reduce radiated noise from pwm outputs. If amplifiers are more than 1m. from power supply capacitor, use a small (200-500 $\mu$ F.) capacitor across power inputs for local bypassing.

# Model 505

## DC Brushless Servo Amplifier

### AMPLIFIER COMPONENT HEADER

#### CURRENT-LIMITS

I-Peak	RH5	I-Cont	RH3	T-Peak	RH4
10A	<i>Open</i>	5A	<i>Open</i>	0.5s	<i>Open</i>
8A	12k	4A	20k	0.4s	10 Meg
6A	4.7k	3A	8.2k	0.2s	3.3 Meg
4A	2k	2A	3.9k	0.1s	1 Meg
2A	750	1A	1.5k		

#### LOAD INDUCTANCE

Load (mH)	RH1	CH2
0.2	49.9 k	1.5 nF
1	150 k	1.5 nF
<b>3</b>	<b>499 k</b>	<b>1.5 nF *</b>
10	499 k	3.3 nF
33	499 k	6.8 nF
40	499 k	10 nF

\* Values in **bold & italics** are factory standard.

### OUTPUT TRUTH TABLE

The table below shows the relationship between the signals at the Hall inputs and the drive outputs. Note that only two outputs are active at any time, the third output is off and neither sources nor sinks current.

Outputs: + = HI/LO active PWM output  
 - = active LO output  
 0 = OFF

Current flow is from + to - when + terminal is HI (+HV), and recirculates through + and - when the + output is LO during a PWM cycle.

The table shown is for a negative voltage at the Ref(+) input. When the reference input voltage is reversed, the same two outputs remain active, but their polarities are reversed. This changes the direction of current through the motor windings, producing torque and rotation in the opposite direction.

Elec. Deg.	60° S2 = OFF			120° S2 = ON			Output States		
	U	V	W	U	V	W	U	V	W
0	0	0	0	1	0	1	+	-	0
60	1	0	0	1	0	0	+	0	-
120	1	1	0	1	1	0	0	+	-
180	1	1	1	0	1	0	-	+	0
240	0	1	1	0	1	1	-	0	+
300	0	0	1	0	0	1	0	-	+

### ORDERING GUIDE

Model 505	5A Continuous, 10A Peak, 55V DC Brushless Servoamplifier with Hall-Encoder Tach
-----------	---